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Abstract

The injection complex of the SuperB, B-factory project of the "Nicola Cabibbo Laboratory" [1], consists of a polarized electron gun, a positron production system, electron and positron linac sections, a positron Damping Ring and the transfer lines connecting these systems to the collider main rings. To keep the ultra high luminosity nearly constant, continuous injection of 4 GeV electrons and 7 GeV positrons in both Low Energy Ring (LER) and High Energy Ring (HER) is necessary. In this paper we describe the baseline design and the beam dynamics studies performed to evaluate the system performance.

INTRODUCTION

For the injection system baseline used in the cost estimate, simple and well tested solutions have been chosen, so that no further R&D is requested and components available on the market are preferred. The scheme, sketched in Figure 1, is flexible enough to allow for the introduction of alternative solutions that can improve performances or reduce costs once their feasibility is proven.

Electrons are produced using a polarized gun like the one used by the SLC collider at SLAC, where a polarization of 80% has been routinely achieved. A single electron bunch (or a short train of up to 5 bunches), with up to 10 nC charge is produced and passed through a sub-harmonic bunching system to reduce the bunch length from 1 ns FWHM down to 10 psec. The charge required for injection into main rings is 300 pC/bunch in 5 bunches. All the 3 linac sections, L1, L2, L3, are based on S-band, SLAC type, accelerating sections with SLED systems operating at 100 Hz repetition frequency. The injection repetition cycle is 30 ms for each beam. This timing scheme allows for acceleration of a third beam with 30 ms repetition cycle. The feasibility of using this cycle for accelerating a ultra low emittance beam for a SASE FEL facility is under study.

Both beams will be stored in the Damping Ring (DR) for emittance damping, as described in [2]. The option of accelerating the electrons from a low emittance polarized gun [3] has been for the moment cancelled, even though preliminary simulations are promising, since it requires further R&D work.

Electrons are accelerated up to 1 GeV in linac L1 and injected into the DR. Positrons are produced by electrons accelerated in linac L1, impinging on a positron converter target. Linac L2 is used to capture and accelerate positrons up to 1 GeV before DR injection. Linac L3 accelerates the two beams up to the main rings energies, 4.18 GeV and 6.7 GeV, respectively.

POSITRON PRODUCTION

The general layout for the low energy positron source is described in [4]. The positrons are created through a target downstream an electron drive beam, are then captured in an Adiabatic Matching Device (AMD) and accelerated with a pre-injector encapsulated in a solenoidal field. A conventional transverse periodic focusing structure is then used to bring the positrons up to the DR energy. In this framework several scenario are analyzed.

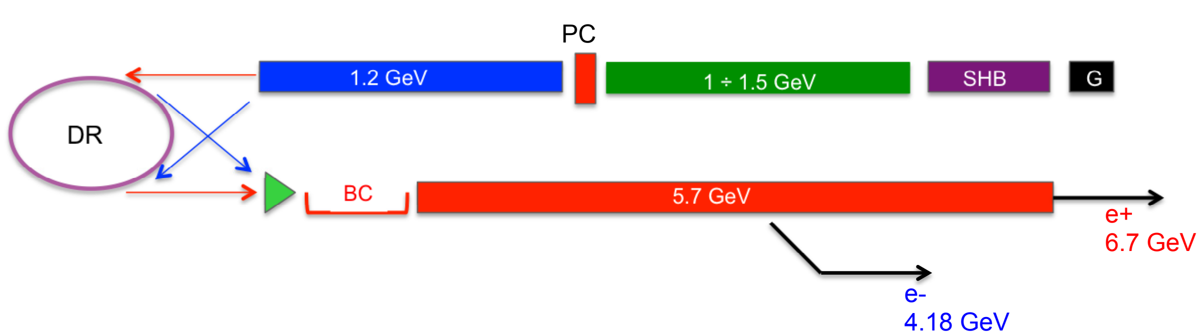

Figure 1: Injection system layout.

S-Band Scenario

In this scenario, immediately after the AMD, the positrons are bunched and accelerated up to 1 GeV by standard, SLAC type, S-Band Travelling Wave structures. The accelerating capture section takes the beam up to the energy of ~ 300 MeV. Then 4 quadrupoles are used to match the beam transverse phase space to the periodic focusing structure.

Two different lattices have been considered: a FODO cell, and a FDOFDO (doublets) cell. The Phase advance per cell is $\pi/2$ in both cases resulting in roughly the same period (~ 4 m).

The positron yield at the end of the linac is reported in Figure 2 as a function of the energy of the drive beam. The yield is calculated for the positrons within the longitudinal and transverse DR acceptance. Both cells present roughly the same behavior; the main difference is the space available for the accelerating sections, 2m for the FODO and 3 m for the FDOFDO. The doublet solution may be preferred since it allows using the same 3 m long accelerating sections used in the other linacs L1 and L3.

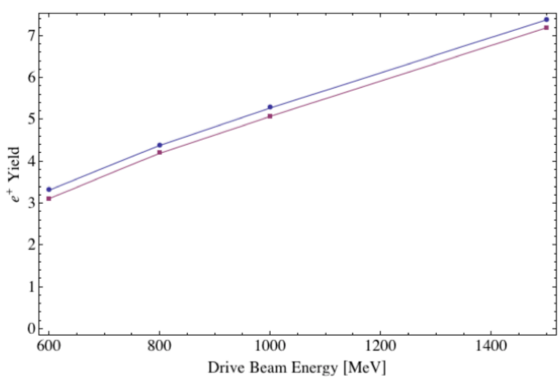

Figure 2: Positron yield as a function of the drive beam energy for a FODO cell (red) and FDOFDO cell linac. The longitudinal and transverse DR acceptance is taken into account.

L-Band scenario

The L-band LINAC option currently studied is based on 1428 MHz "travelling wave" cavities (aperture radius of 20 mm), with constant gradient and TM010-2pi/3 mode, room temperature technology. Below 300 MeV the 4 accelerating structures (6.108m long) are made of 84 copper cells and 2 couplers. At higher energy the 27 accelerating structures (1.489m long, 26MV/m) are made of 18 cells and 2 couplers. The magnetic field generated by the AMD decreases from 6 to 0.5T in 0.5m, then a constant solenoidal magnetic field of 0.5T covers the first 4 accelerating tanks. Five quadrupoles are used to match this section to the following one where FODO cells focusing is used. With a 600 MeV incident electron beam impinging on a 9mm thick tungsten target and a 84 m long L-band LINAC, a 1GeV positron beam with 3 mm bunch length and relative energy spread within +/-1.5% can be achieved with a yield of 19%. This scheme has been studied for different incident electron beam energies from 400 MeV to 1GeV with an optimized target thickness. An hybrid scheme with L-band accelerating sections below 300 MeV and S-band at higher energy is under study.

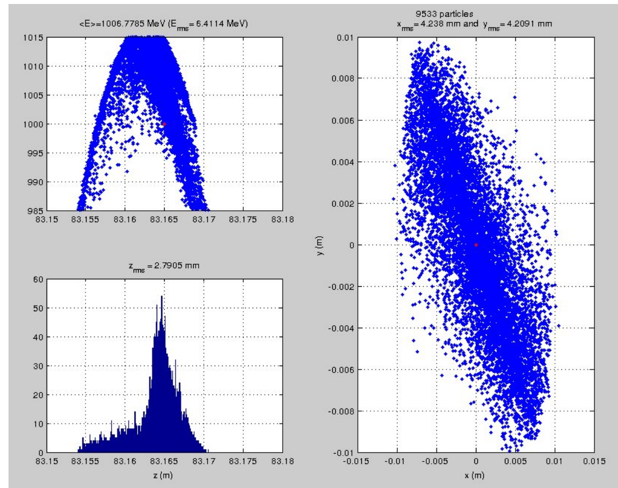

Figure 3: Positron beam distributions at 1 GeV within $\Delta p/p$=+/-1.5% produced by a 600 MeV electron beam with a yield of 19%.

BEAM DYNAMICS STUDIES

Simulation of Coherent Synchrotron Radiation in the DR showed that no instability should arise, since radiation is well suppressed by the chamber shielding [5].

For both beams a start-to-end simulation has been performed starting from the DR extraction septum, up to the end of the high energy linac L3. A bunch compressor is located at the end of the E2 and P2 transfer lines, connecting the DR to the L3 linac [2, 6], to minimize the energy spread of the beam after acceleration in the linac and optimize injection into the main rings.

Table 1: Start-to-end Simulation Parameters

	DR exit	Linac end
	ELECTRONS	
Energy (GeV)	1.0	4.18
Bunch charge (pC)	300	
Emittance ε_x (nm)	23	5.5
Emittance ε_y (nm)	0.20	0.047
Bunch length (mm)	4.8	0.67
Energy spread $\Delta p/p$ rms	6.2e-4	1.6e-3
Energy spread $\Delta p/p$ 99%	±1.9e-3	±4.3e-3
	POSITRONS	
Energy (GeV)	1.0	6.7
Bunch charge (pC)	300	
Emittance ε_x (nm)	28	4.2
Emittance ε_y (nm)	5	.075
Bunch length (mm)	4.8	0.67
Energy spread $\Delta p/p$ rms	6.2e-4	1.3e-3
Energy spread $\Delta p/p$ 99%	±1.9e-3	±3.6e-3

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The beam parameters at DR exit and at linac end are listed in Table 1 for both electrons and positrons.

The plot of the longitudinal phase space at the end of the linac for the electron beam is shown in Fig. 4 and the electron horizontal rms beam size from DR to end of linac is shown in Fig. 5. The high peak in the horizontal beam size corresponds to the bunch compressor chicane.

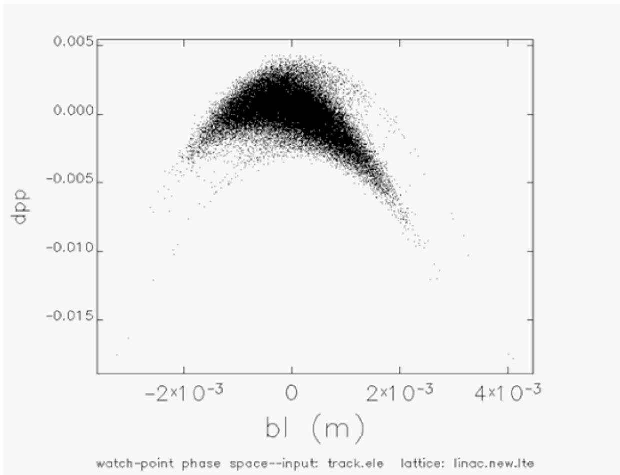

Figure 4: e^- longitudinal phase space at the end of the linac.

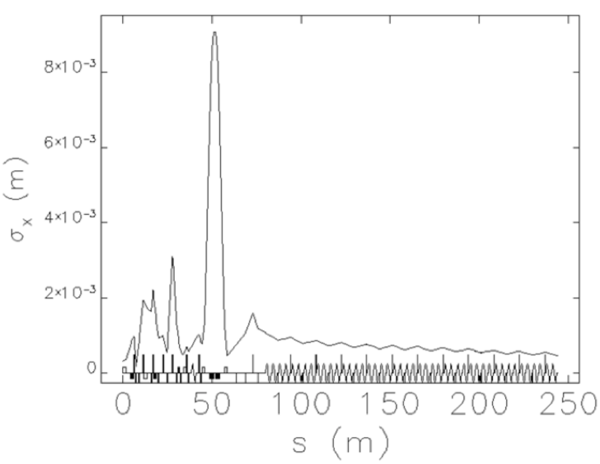

Figure 5: e^- horizontal rms beam size from DR to end of linac.

BEAM-BEAM SIMULATIONS AT INJECTION

Simulations of the injected beam together with beam-beam interactions have been carried out [7], showing that the effect of the crab sextupoles is beneficial. In Fig. 6 the vertical emittance evolution of the injected beam for 50000 turns, corresponding to ~8 damping times is shown. The green line is for the case with crab sextupoles OFF, the blue one for crab sextupoles ON.

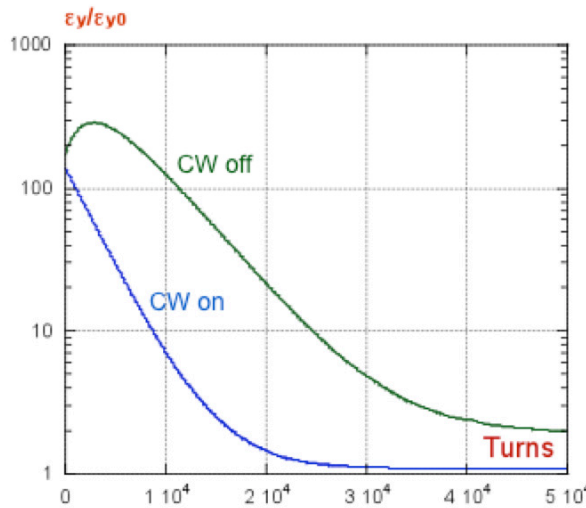

Figure 6: Vertical emittance evolution after injection for 8 betatron damping times for crab sextupoles OFF (green) and ON (blue).

For crab sextupoles OFF there is an emittance blow up of a factor 3 soon after the injection, largely outside the vacuum chamber aperture, and an equilibrium emittance a factor 2 larger than the nominal one. For crab sextupoles ON the emittance damps down to the nominal value as in the case without beam-beam effect in less than 4 damping times.

CONCLUSIONS

The baseline configuration for the SuperB injection system has been selected. Beam dynamics studies performed up to now confirm the expected performances. Work is in progress with the objective to produce a complete start to end simulation for both beams in order to evaluate the system performance.

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